MOBILE EXPERTS

EXPERT INSIGHT FOR HANDSET SUBSCRIBERS

5G mm-wave Handsets:

Will people buy them?

Introduction

Handset OEMs are scrambling to make millimeter-wave handsets available. And it's easy to understand why: Multiple top operators are deploying networks at 24 – 39 GHz and asking for handset options.

Even while the industry gallops toward mm-wave radio options, serious risks remain. With millimeter-wave technology:

- The user's hand will block the antennas on a smartphone or tablet.
- The link budget for a smartphone will be heavily out of balance.
- The mm-wave radio will consume a lot of battery power.
- The mm-wave radio will take space inside a smartphone.
- Millimeter-wave capability could add $20-30 to the BOM cost of a smartphone.
- So far, no 'killer apps' have arrived to force users to buy a 5G phone.

This Expert INSIGHT explores these questions and their solutions…to predict whether end users will actually buy 5G mm-wave smartphones, or whether subsidies or hotspots will be preferred solutions.

Figure 1: Motorola's 5G MOD handset for mm-wave operation

Sources: Verizon

Technical Factors – Battery Life

The mm-wave radio can impact the battery life of a smartphone in two ways:

1. The use of three or four mm-wave sub-arrays reduces the space available inside the phone, forcing the OEM to reduce battery size.
2. The mm-wave radio can be power-hungry, consuming 1-2W of raw power during operation.

Starting with the first factor, we estimate that the new Qualcomm QTM052 module is about 20mm x 5 mm x 2.5 mm, and in most handsets either three or four sub-array modules would be used. Each sub-array includes up/downconversion and would be connected to a central RFIC/modem by a microstrip trace on the main PCB.

Overall, we estimate that the space taken by the mm-wave function comes to roughly 900-1500 cubic millimeters in a smartphone. Lithium-ion batteries store energy at roughly 0.15 mAh per cubic millimeter, so this is the equivalent of about 150-200 mAh. In a premium smartphone, adding mm-wave can reduce the battery size by 5-10%.

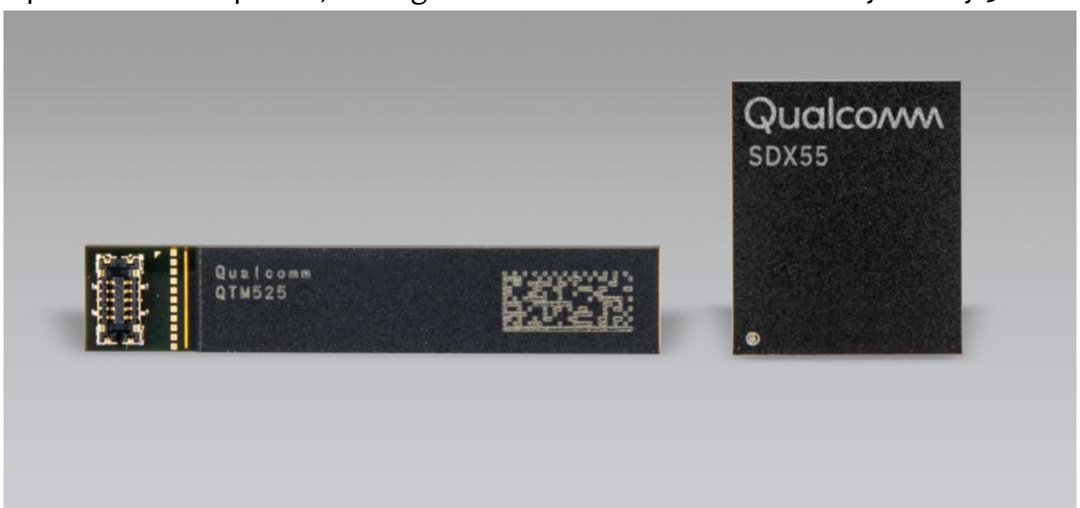

Figure 2: Qualcomm's mm-wave subarray and X55 5G modem

Sources: Qualcomm Technologies, Inc

Secondly, the mm-wave radio consumes power. This one is more complex, because in fact the mm-wave radio can SAVE power by completing a download more quickly. We consider two scenarios:

Scenario 1: Big Download (5 GB file)	Download Speed	Power Draw at 3.5V	Energy Consumption for a 5 GB file
5G mm-wave system (3 sub-arrays assumed)	1 Gbps	1.8W total (4 active PAs), 10% duty cycle for uplink	Roughly 7.5 mAh
LTE RF Front End (FDD)	100 Mbps	1.1W total	Roughly 440 mAh

In the case of a movie download, an LTE link can take 15 minutes and consume 20% of the battery life in a phone… but a mm-wave radio can complete the download in 40 seconds and consume far less energy in total.

Scenario 2: Video Chat (1 hour)	Power Draw at 3.5V	Energy Consumption for 1 hour
5G mm-wave system (3 sub-arrays)	1.8W total (4 active PAs), 50% duty cycle for uplink	Roughly 3200 mAh
LTE RF Front End (FDD)	1.1W total, 50% duty cycle for uplink	Roughly 2000 mAh

Our second scenario does not look as favorable for the 5G case, assuming an application that requires the uplink to be active constantly. Note that in today's video chat applications, the uplink may still be able to 'sleep' for most of the time… but we are assuming an ultra-high resolution future application where the Gbps capability would be used at 50% duty cycle. We compare to today's video chat where the LTE radio would be active roughly 50% of the time.

The conclusion: The impact of 5G on battery life is not likely to be a problem. The physical space reduces the battery size, but quicker downloads and uploads can offset the losses to make a 5G phone similar to an LTE phone for battery life. If new applications arise that require the transmitter to be active constantly, then the handset will have battery problems and heat dissipation problems.

Technical Factors – Link Budget

In field trials for 5G mm-wave, the performance has been absolutely limited by the uplink. Engineers involved with the trials indicate that the uplink is at least 10 dB weaker than the downlink, mainly due to the low EIRP in the UE devices.

The Netgear CPE is one product that is available on the open market, with information available at the FCC. The EIRP of this product is only +15 dBm, compared with +40 dBm or so in CPEs offered by Samsung and Ericsson.

Figure 3: The Netgear 5G mm-wave hotspot

Sources: Netgear

What's the impact if the uplink link budget is weak? Even though the majority of data will be in the downlink, the uplink must be able to close the loop. The uplink is necessary for channel modeling to set the beamforming and other parameters in the 5G waveform. There's some R&D activity surrounding the use of low bands (1-3 GHz) for the uplink, and 28 GHz in the downlink…but to our knowledge this technique is not ready for the field.

Recent field testing indicates that the Netgear product (at +15 dBm EIRP) was able to connect up to 200m, but lost its connection at 250 meters with line-of-sight to the base station (at 39 GHz). Recent consumer reviews of the Motorola MOD handset have been scathing, with HORRIBLE results, even in excellent locations, due to changing channel conditions. Similar tests with Samsung and Ericsson CPEs (at +40 dBm EIRP) have demonstrated 1 km link distance at 28 GHz. Despite the difference in frequency band, the

EIRP of the user device is clearly a strong factor in link distance. This translates into strong economic leverage for the operator. If the operators can deploy HALF the number of base stations for coverage, that's a multi-billion dollar network savings.

Technical Factors – Antenna Placement

One of the most difficult issues to solve will be the placement of antennas on client devices, so that the user can't cover the antenna with his/her hand. This is a killer issue, because a human finger over an antenna will cause 30-50 dB of attenuation at a minimum.

The first idea is to place sub-arrays on all sides of the handset. That's a good start, but gamers tend to hold their phones in both hands, covering both ends of the handset and possibly impairing the center as well.

The next step: Handset OEMs are exploring the adoption of foldable form factors. Over the last 3 months, a few models have been floated in public and the reaction has been fairly positive so far. A lot of questions remain with regard to durability and display quality, but people like the idea of a larger display.

Beamforming options will also become more sophisticated. Recent modeling from Qualcomm indicates about 5 dBi gain from the antenna system on a handset form factor. In other words, a 5 dBi beam can be steered in three dimensions from a typical mm-wave smartphone with a hand blocking a few of the antenna elements. We believe that clever placement and clever beamforming processing can increase the gain to +10 dBi or so, and the EIRP can be raised on a handset without violating any health & safety regulations.

Of course, another solution will be to use a mm-wave hotspot so that the smartphone can operate using 5 GHz Wi-FI. This approach would allow for higher numbers of antennas, a big battery or even plug-in operation, and will not have the same problems with hand blockage. We believe that a hotspot product can easily achieve EIRP in the +40 dBm range, reaching the same level of coverage performance seen in Verizon and AT&T trial systems.

Business Factors

The operators seem to get all of the benefits of 5G. End users will see faster speed, but for the applications on the market today, faster speed will not really change the user experience. But the operators will enjoy dramatically lower cost per bit, as well as higher capacity for additional users and new revenue from the fixed-broadband market.

As a result, we believe that the operators will be forced to subsidize 5G UEs. Smartphones are already viewed as "too expensive", with premium phones over $1,000. We don't believe that another $30 in BOM cost ($100+ adder to the sales price) will be acceptable to a typical consumer, especially if there's an issue with hand placement on the phone.

So, the operators will need to incentivize their customers to move to a 5G device. In the United States, this means that the operators would be likely to reduce the cost of a $1,000 smartphone by a few hundred dollars, and discontinue incentives for non-5G phones.

Another option will be for US operators to give away free hotspots. A 5G mm-wave hotspot (without an LDC display, apps processor, or other features) could cost about $300. A free hotspot may be more attractive to end users than a $300 discount on a 5G phone.

What's the Most Likely Outcome?

It's too early to see any meaningful data from the open market. The Netgear hotspot and the Motorola 5G MOD phone are simply the first products, and each one has its flaws. In the end, we see multiple key factors:

- The operators have a strong incentive to move customers to mm-wave bands.
- Handsets have technical problems and the cost of 5G mm-wave will be high.
- Hotspots are cheaper than handsets and still accomplish the 'offload' of the LTE bands, although large numbers of hotspots are likely to clog the unlicensed bands.

- CPEs will provide home broadband coverage and are likely to be spaced apart better than portable hotspots. Partial offload for home-based usage could be enough for the operators to achieve their capacity and cost-reduction goals.

Our conclusion: Millimeter wave smartphones will be on the market, but there's a strong chance that hotspots or CPEs will ship in equal or even higher numbers.